Linking a Respiratory Drop's Size to Its Origin

A parameterization scheme that links a drop's size to its origin in the respiratory tract could help clinicians identify the most effective mitigation strategies for halting the spread of an infectious disease.

By **Katherine Wright**

Flu season is upon us—this month my household has already come down with coxsackie, runny noses, and coughs that just won't go away. Key in the transmission of all these illnesses are pathogen-laden water drops that spray from a sufferer's mouth and nose whenever they breathe, speak, sneeze, or cough. Now Christopher Pöhlker of the Max Planck Institute for Chemistry, Germany, and his colleagues present data that link the sizes of these drops to where and how they originate in the respiratory tract [**1**]. This information could aid in increasing the efficacy of medical treatments of infectious diseases and in identifying the most effective mitigation strategies for avoiding their spread.

The efficacy of a mask in halting the spread of a respiratory infection depends on the size of the drops in which the infection travels.
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Like many researchers, Christopher Pöhlker joined the study of infectious diseases at the beginning of the COVID-19 pandemic. An atmospheric scientist by training, he and his research group normally examine airborne particles in forest ecosystems. But stuck at home during the shutdown periods of early 2020, he and his wife Mira Pöhlker, a cloud scientist at Leipzig University and the Leibniz Institute for Tropospheric Research, both in Germany, decided to delve into the literature of respiratory drops, hoping to find science-based answers for how this disease was spreading. “We were under the naive assumption that the properties of respiration particles—which are relevant not just for the spread of COVID-19 but also for influenza, tuberculosis, and many other diseases—are so fundamental that the very basics should be settled,” Christopher says. “That turned out not to be the case.”

As part of the literature deep dive, Christopher and Mira teamed up with other drop experts to collate publicly available information on drop properties, such as size distributions, compositions, and emission pathways. The culmination of that effort is a parameterization scheme that classifies drops into “modes,” with each mode associated with a characteristic size distribution and a specific origin in the respiratory tract. “Modes have meaning,” Mira says. “In the atmosphere, a particle's size is linked to its source. We show that is the same for respiration particles, and we can explain all the distributions measured so far.”

The researchers define five drop modes. They assign the smallest drops, those with diameters of less than 0.2 μm and those between 0.2 and 1 µm, to two so-called bronchiolar modes. Drops in these two modes are generated by the bursting of liquid films that span the narrowest passages of our airways. These films form when we breathe out and the passages close. When we breathe in, and the airways reopen, the films then pop, creating drops.

The initial trajectories of drops made this way cause the drops to go farther into the lungs before escaping the mouth. As such, scientists in the field think that the drops may pick up pathogens along the way. These drops could thus play an important role in transmitting bacteria that infect the lungs, such as tuberculosis bacteria. "But that's still an open question," Christopher says.

The infection potential of small drops may also depend on the age of the sick person. Children have been found to breathe out significantly fewer small drops than adults, says team member Eberhard Bodenschatz, a fluid dynamics expert at the Max Planck Institute for Dynamics and Self-Organization in Germany. That finding suggests that "adults are much more likely to trigger spreading of the disease if the infection is only in the lower respiratory tract, where small drops are produced," he adds.

At the other end of the size spectrum lie the drops of the two so-called oral modes, which, as the name suggests, mostly originate from the mouth, tongue, and lips. These drops have diameters of 8 to 15 µm and 60 to 130 µm and are produced, for example, when we speak or laugh. Mouth-spanning saliva filaments can form when we open our mouths and then rupture when we exhale, spraying spit on anyone standing too close (see **Research News: How Talking Spreads Viruses**). Other drops fit in these modes, such as those that originate in the nose and throat and form after the destabilization of a mucus film, for example, when we sneeze. If the pathogen resides in the upper respiratory tract, Bodenschatz says that it is these large drops that are likely the main transmitter of any infection. "These can be really large drops," Christopher says. "Large enough to see."

In between the bronchiolar and oral modes lies the larynx–trachea mode. Drops in this mode originate in the vocal folds. Scientists hypothesize that, as air speeds over these mucus-bathed features, the sheer stresses are so large that they can tear off bits of this slime. Another possibility is that vibration of the folds destabilizes the top layer of the mucus pool, which then fragments into tiny gunky beads. This mode is activated when someone laughs, speaks, sings, cries, or coughs, for example. Christopher says that this mode is known to be crucial for spreading tuberculosis, which is typically passed on through coughing. Yet the formation mechanisms of this mode are the least understood.

Also unknown is exactly how a drop's size correlates with its infection potential. Scientists know that the small bronchiolar drops can form aerosols with lifetimes of hours or more, increasing the possibility that they will be inhaled by another person. The origin of these drops in the lungs also coincides with a key infection site of severe respiratory infections. However, their small size suggests that they likely contain the fewest pathogens, which could reduce their infection potential. Whether a drop is involved in spreading a respiratory virus depends on the size of the drop, the severity of the infection, and the location of the pathogens in the respiratory tract, Christopher says. "But there are almost no data that allow us to assess in which mode the pathogens are traveling. Making that link is a key task for the future."

That task will require human studies. The creation of drops by the respiratory tract can be mimicked in the lab, but that's not yet possible for viral infections. Bridging that gap requires scientists and clinicians to work together. But once scientists know more about which modes transport pathogens, Mira says, the most effective anti-transmission measures will become clearer. For example, if the virus travels mostly via oral modes, then a surgical mask is enough to halt transmission. But if instead it moves in bronchiolar modes, a KN95 mask should be donned. "Size is one of the most critical parameters in thinking about how to stop a virus spreading," Christopher says.

"This [study] is a valuable, thorough contribution" to our understanding of drops in the context of disease transmission, says Howard Stone, who studies fluid dynamics problems related to virus spreading at Princeton University. Fluid physicist Detlef Lohse agrees. "The group has collated a huge amount of data in a way that is tremendously useful," says Lohse, who works at the University of Twente in the Netherlands. Lohse notes that with the explosion of respiratory drop research at the start of the COVID-19 pandemic, there was some miscommunication among fields because of differing uses of nomenclature. “A drop is a drop, but different communities called them different things. It was bizarre,” he says.

Lohse thinks that this miscommunication likely contributed to the confusion about transmission mechanisms early in the pandemic. “This puzzlement of languages between communities meant the right actions were not taken quickly enough,” he says. For that reason, the new results have potentially life-and-death consequences. “In a sense it’s an empirical study—but it unifies all the information and gives everyone a framework from which to work,” he says. “That’s important if we want to be ready for the next pandemic.”

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REFERENCES

1. M. L. Pöhlker *et al.*, “Respiratory aerosols and droplets in the transmission of infectious diseases,” **Rev. Mod. Phys. 95, 045001 (2023).**